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Computationally Efficient Thermal Management for Electric Vehicle

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ABSTRACT

The thermal management system, which is in charge of keeping the battery at the right temperature, uses a lot of power, especially when it comes to keeping the battery's temperature low. To get the most out of the vehicle's driving range, the batteries need to have the best temperature control systems possible. A model is used to describe the parts of a battery cooling system by showing how it uses energy and transfers heat. To make the modelling process easier, some assumptions are made. To make a stochastic model of future heat production that can be used in real time, it is important to include a probability distribution with gaps between the numbers. This is because the model needs to be right in order to work in real time. The proposed control method uses a lot less energy than other temperature sensors, like a thermostat or a model predictive controller that only uses data about what will happen in the future. This is done while keeping the temperature regulation performance at a good level. Even though the way the temperature is controlled hasn't changed in any way, this is still the case.

Keywords: Arduino; Current sensor; Voltage sensor; Temperature sensor; Relay; Peltier cooler.

1. Introduction

The market for electric vehicles (EVs) is growing, and lithium-ion batteries (LIBs) are currently the leading technology in this field. Large sums of money have been spent on researching and creating better batteries and electric cars in recent years. Component makers for electric vehicles have been vocal about their plans to switch to electric power [1]. Electric vehicle (EV) sales were strong in 2020 despite the market disruption caused by Covid-19. This helped the market to recover. The market value of LIB cells used in electric vehicles is expected to hit nearly $70 billion by 2026, according to sources [2],[3]. Estimates for the electric vehicle, bus, van, and truck markets, as well as an analysis of market drivers and restraints [4],[5] form the basis for the aforementioned statement. In recent years, LIB (lithium-ion battery) production has skyrocketed. The proliferation of electric vehicles and the development of the consumer electronics market, especially in the field of smartphones, are both factors in the aforementioned occurrence. Lithium-ion batteries (LIBs) are expected to become more plentiful in the coming period [6] as a result of rising demand. The battery pack's performance suffers at temperatures below its optimal range. Due to chemical reactions and electrolyte breakdown, capacity rapidly decreases as temperature rises. LIBs can only function properly and last as long as intended if their operating temperature is kept constant.

Temperatures should be kept between 20 and 40 degrees Celsius, with no more than a 5-degree temperature difference between different parts of the battery pack, as stated by various sources [7]. The longevity of the battery and its safety may be compromised in the event of sudden temperature variations [8] due to the inherent limitations of LIB components in accommodating significant fluctuations in temperature and exhibiting unstable chemical reactions. The damage done by this may be permanent. If the LIB's thermal management system is unable to keep the temperature within a certain range, the battery could overheat during the charge and discharge cycles. The aforementioned factors greatly increase the potential for fire and explosion [9],[10].

The problem may become much worse when many cells are connected to one another in either a series or parallel arrangement [11]. High temperatures cause a steady increase in energy density, but they also hasten the breakdown of batteries [12]. By increasing internal resistance, low temperatures reduce the battery's efficiency while charging and discharging. Additionally, uneven temperature distribution between cells or segments can significantly reduce battery efficiency and hasten deterioration.

2. Existing Method

We referred one of existing system IOT-Based battery parameter monitoring system for Electric Vehicle. This System’s planned use of the IOT to track an electric vehicle battery’s performance is described. The battery serves as the only energy source for electric vehicles. Yet, the energy given to the vehicle is steadily reducing, which lowers performance [13]. The manufacturing of batteries is quite concerned about this. In this suggested approach, the notion of observing to measure the vehicle’s performance. According to this paper results, the system is able to recognise diminished battery performance and notifies the user for further action.

The voltage, current, and remaining charge capacity of the battery are estimated in a real-time situation in the suggested system. This project built a PIC-based system to design a data gathering system to track these battery properties. Furthermore, information is kept on a server database and shown on an Android mobile device [14]. The voltage sensor is capable of keeping track of voltage of up to 25V DC and the current sensor is capable of measuring up to 5A of current. The battery’s temperature will be measured by the temperature sensor, the outputs of the current, voltage and temperature sensors are analogue in nature, so there are convert them into digital format.

A microcontroller with the PIC18F4550 model number from Microchip Corporation was used in the development of this software. The controller is in charge of analysing the data sent in by the sensors and displaying the results on the LCD screen. The data is also sent to NodeMCU so that it can be uploaded to the cloud with minimal effort [15]. The NodeMCU has built-in wireless networking capabilities. Android users can also get their hands on this data by downloading an app. To retrieve information from the cloud, one needs a "read" API key, while "write" API keys are required for storing information in the cloud. This is done to make monitoring less of a hassle [16].

The research made use of an Android smartphone linked to a web-based app. When the battery is full, the app shows the Battery parameter Values, and when it is empty, it shows the values. This system was proposed as an integral part of a larger system for real-time monitoring of lithium-ion batteries [17]. A battery's voltage, current, and temperature can all be measured and displayed on a mobile device. This can occur in the moment. To prove the viability of the technology, a working model was built [18].

3. Proposed System

In order to avoid battery damage, prolong battery life, and prevent fire or explosion, batteries used in EVs shouldn’t be overcharged or over released. To increase the energy density of the batteries used in electric vehicles (EVs), it is absolutely necessary to set up a reliable battery management system (BMS). The Battery Management System (BMS) does many things, and one of them is to keep an eye on the battery's charge, health, and performance. Even though this recommendation could change based on how the battery's electrochemistry is made, most people agree

that a temperature of 45 degrees Celsius is the best setting to keep the battery life of an electric vehicle at its best. Before a true picture of the cooling process can be made, it is necessary to build models of both the cooling mechanism and the cooling cycles. Multiple studies used a model that was found to be too simple in the end because it didn't take into account the processes that cause heat to be lost and cooled. This is because the main goal of the studies that came before this one was to show that the proposed ways to control the problem worked. Based on a simple but accurate model of the cooling system, the current study suggests an MPC-based battery cooling controller. This model is based on studies that have already been done. The model can accurately show how well both the parts and the actuators work. It can also include useful information about what will happen in the future. The model's accuracy can be improved by using a control-oriented strategy that takes into account both the physics of how heat moves and how well each part works. The proposed system alerts the user, whenever the battery gets charged, by using a temperature sensor to sense the heat in the battery. In a battery cell, the movement of electrons causes electrochemical reaction and joule heating. Li-ion batteries perform best at temperatures between 25^{o}C and above 40^{o}C, and if the temperature rises above 45^{o}C , it becomes hazardous to the battery's lifespan. Immature degeneration in even a single cell can significantly lower the battery pack's overall performance and efficiency.

The proposed system includes a current sensor, a voltage sensor, and a temperature sensor, all of which work together to keep an eye on the condition of the electric vehicle's battery. A temperature sensor, an ACS712 current sensor, and a fixed LCD are used to keep an eye on how well a battery is working all the time. These sensors are used to measure the temperature, current, and voltage of the battery, in that order. This is done to see how well a battery works. When the bike reaches a certain temperature, the peltier cooler, which is a common way to cool things down, can be turned on. By using a relay, you can keep the bike from getting too hot, which would make it stop working.

4. System Block Diagram

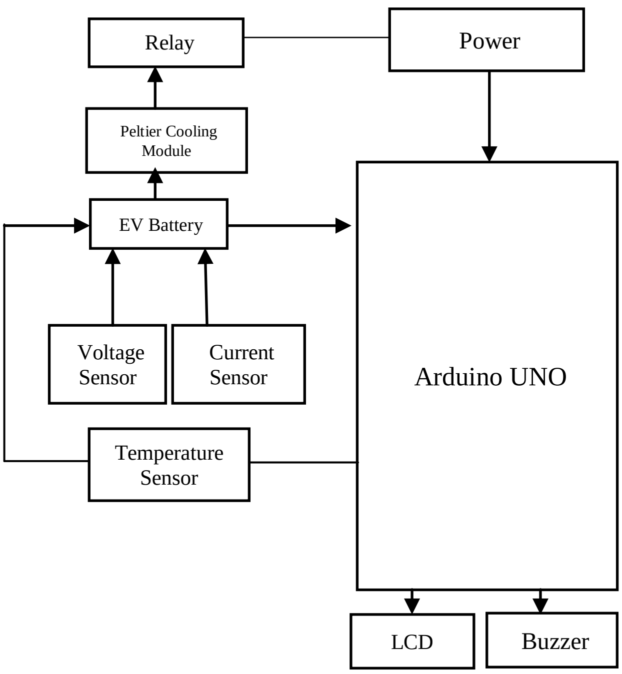


Figure 1. System block diagram

The design blocks in Figure 1 provide a high-level overview of the proposed BMS system and Cooling System, which consists of a sensor network, cooling module, Relay and microcontroller.

5. Related Work

(a) Arduino UNO Microcontroller

The advantages of using an Arduino over other types of microcontrollers include its open source nature and lower cost. A greater number of professionals use programming since it is simple. The Atmega328 family includes the Arduino (Figure 2). Analogue and digital input/output pins can be found on Arduino. The 5V DC supply is needed to operate an Arduino board.

In order to collect data and control motors, the Arduino UNO is at the centre of this project. The input/output pins on the Arduino board are connected to the sensors that control the environment and the LCD display. A connection is made between the control circuit and the output pins of the Arduino board has a USB connector, the reset button, and pins for attaching external sources. Additionally, a transmit pin and a serial monitor pin are present. 5V and 3.3 V are produced as output by Arduino.

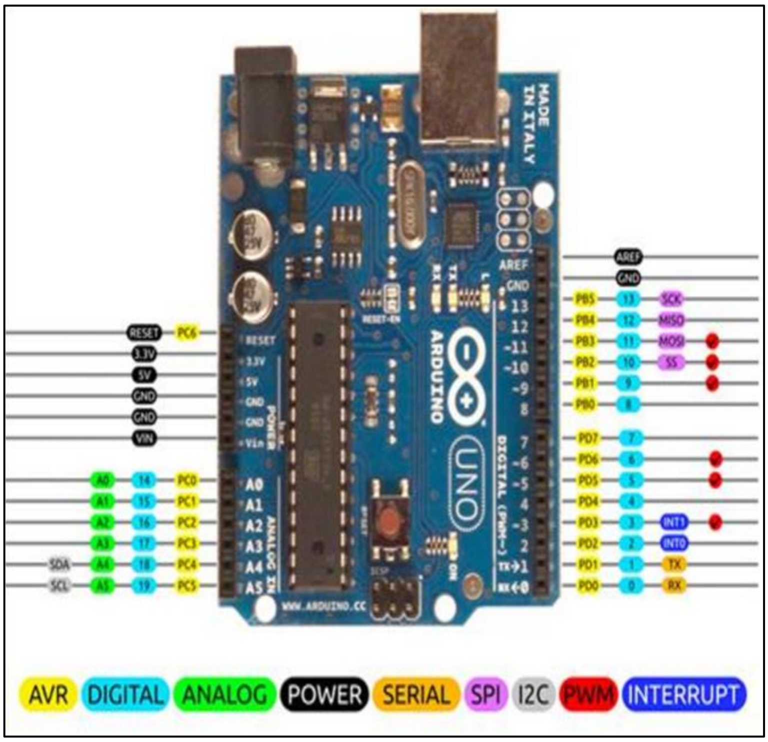


Figure 2. Arduino UNO Microcontroller

(b) System flowchart

Figure 3 presents a visual representation of the flow of the source code for the system. After turning on the power to the system, the initialization procedure will immediately begin.

With the assistance of the appropriate sensors, it is possible to monitor the temperature of the battery in addition to the voltage and current levels. These sensors send data, which is then received by an LCD and an Arduino microcontroller, which then displays the data to the user.

The cooler system receives data from the temperature sensor in order to create cooling of the battery as well.

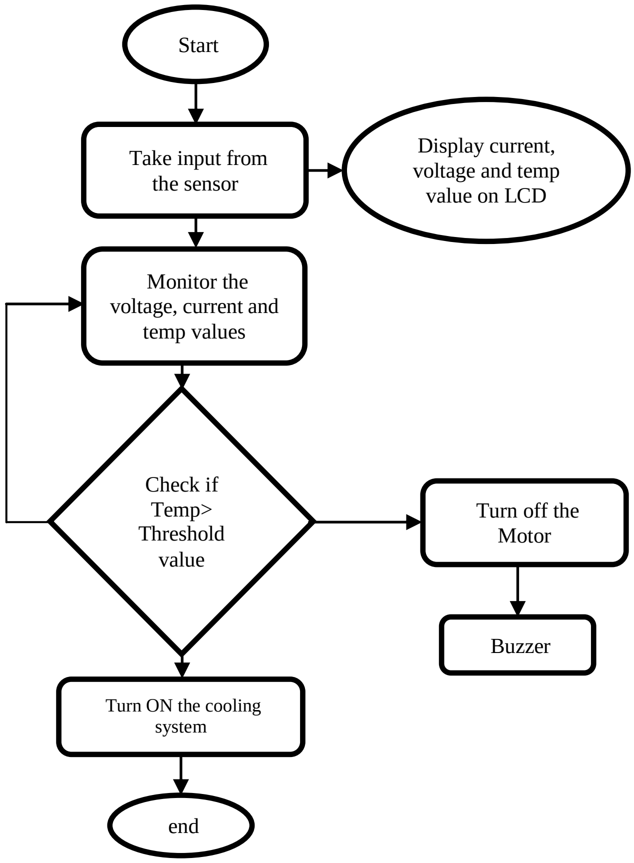


Figure 3. System Flow Chart

(c) Voltage Monitoring

The performance and range of an electric vehicle are significantly influenced by both the capacity and efficiency of its battery pack. The Battery Management System (BMS) keeps tabs on the battery pack and makes sure it's operating at peak efficiency. Among the many important roles that the Battery Management System (BMS) plays in an electric vehicle is keeping tabs on the cells, keeping them in check, and protecting them from overheating. The most important aspects of the battery management system have been discussed at length in this essay.

Table 1. Voltage measurement results

Battery	Voltage measurement results		Accuracy percentage (%)
	Voltage sensor	Multimeter	
1	3.81	3.79	99.47
2	9.98	9.91	99.29
3	8.70	8.55	98.27
4	1.25	1.23	98.40
5	3.81	3.79	99.48

The lithium battery pack's Battery Management System (BMS) will initially check the condition of each individual cell to assess the situation. The BMS would start this procedure before taking any other action. Measurements of voltage, current, and temperature are taken from each individual cell in the pack. Using this information, the Battery Management System (BMS) can carry out a number of tasks, including cell balancing and state-of-charge calculations. The ability to precisely measure the voltage, current, and temperature of individual cells is essential for any Battery Management System's (BMS) ability to effectively manage a battery system in any setting. This criterion applies not only to relatively simple systems like those found in solar batteries and electric vehicles, but also to more complex ones. One can learn how to precisely measure the voltage of individual lithium battery cells.

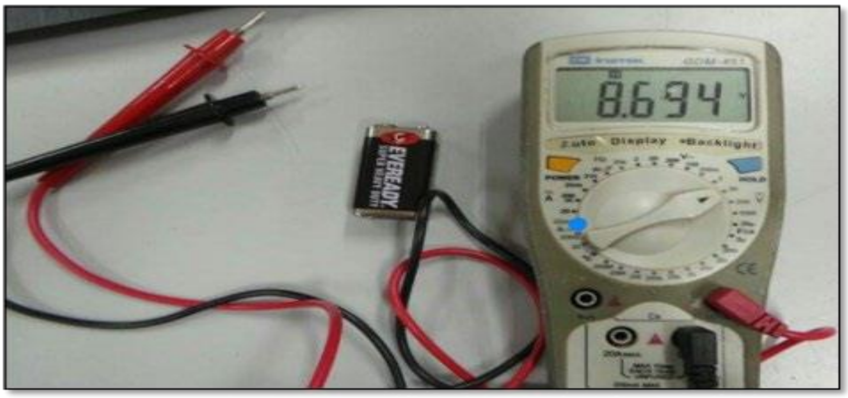


Figure 4. Battery voltage measurement using voltmeter

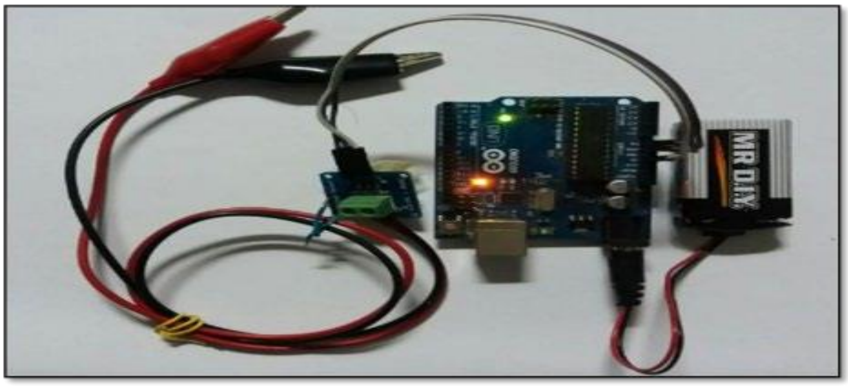


Figure 5. Battery voltage measurement using voltage sensor

The outcomes of the experiments are shown in Table 1. The values in the table are varied from one another because the batteries. The findings demonstrate obtained from the voltage sensors is quite comparable to those obtained using a multimeter. In light of this, it can be said that the voltage sensor accurately measures the batteries.

(d) Current Monitoring

There has been a significant rise in the number of people interested in electric vehicles all over the world. It is anticipated that there will be a growth in the global market for hybrid and electric vehicles as well as bicycles, with a total of 125 million units sold by the year 2030. Battery management systems (BMS), on-board chargers, direct current (DC) to direct current (DC) converters, and traction inverters are all essential components of the powertrain of an electric vehicle (EV). These components require precise current measurements in order to control the flow of energy and achieve the highest possible level of system efficiency.

High-voltage subsystems are essential in order to successfully measure extremely large currents at extremely high common-mode voltages. In order to ensure isolation and optimal performance under harsh automotive conditions, the current measures necessitate the fulfilment of particular mechanical and controlling requirements. There is a possibility that the rapid and localized data acquisition made possible by electric bicycles will lead to an improvement in bicycle safety. Monitoring the electric current that circulates through the various subsystems of an electric vehicle is critical to ensuring that the vehicle operates reliably.

Figure 6. Current Sensor

Allegro ACS712 offers affordable and precise solutions for sensing DC or AC current in industrial, commercial, and communications applications. The circuit whose current has to be measured is linked to this sensor in series. Figure 6 display the ACS712 current sensor module.

(e) Temperature Sensor

The most popular method of monitoring motor temperature is by temperature sensor, which are also used track temperature increases in the battery. When the temperature rises above a certain point, the cooling system will activate, and the vehicle's motor will be cut off via a relay. The LM35 is a precision IC temperature sensor that produces data proportional to temperature and is used as a temperature sensor.

Figure 7. Temperature Sensor

The battery's internal and external temperatures have a significant role in determining how the battery operates since temperature changes can be made automatically. The LM35 temperature sensor, a simple temperature sensing device used in the remote battery monitoring system, is powered by the 5V supply during this investigation. The sensor's readings have a linear relationship to the ambient temperature. The microcontroller's built-in A/D converter was utilised for the output estimation. Using the manufacturer-supplied alignment algorithm, we were able to convert the voltage sign to a temperature to within 0.5 degrees Celsius.

(f) Relay Module

The suggested technique makes use of the 5V relay, which is connected to the Arduino directly (Figure 8). The relay receives a temperature value from the Arduino and outputs it as the battery output. In this, work, a single pole, single throw switch relay is used, and if the Arduino notices an irregularity in the data acquired, it sends a command to it. The relay has 5 pins a common pin, 5V, GND, NO (usually open), NC (usually closed) and 5 pins total. When power is provided to the relay, it acts like an electromagnet and changes the switch's state. This is how a relay operates. The power for the Arduino is independent of the power that is turns on and off.

Figure 8. Relay Module

(g) Thermoelectric modules

Elements of n and p type thermoelectric material sandwiched between two ceramic plates and joined in series make up the basic construction of thermoelectric modules. The components are solid-state peltier that operate without noise or vibration and transfer heat from once surface to another surface when direct current electricity is delivered to them. This assembly turns into a cooling unit if a heat sink dissipates the heat from the hot side to the surrounding air. The thermoelectric module is frequently used in military, medical, industrial, consumer, scientific/laboratory, electro-optic and telecommunications industries for cooling since it has no moving parts, is small in size and is light weight.

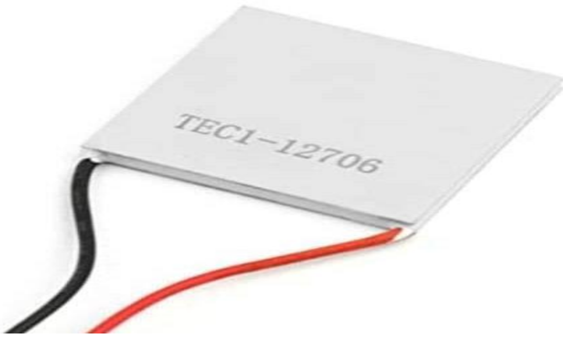


Figure 9. Thermoelectric cooler Module

Thermoelectric (TE) modules are made up of a number of connections between two distinct semiconductors coupled in series. According to figure 10, the two semiconductors are made of n and p type materials. The peltier effect occurs at the intersection between these two different conductors. Heat pumps up and moves from one side of junctions made of n and p semiconductor materials to the other when electricity is applied to them.

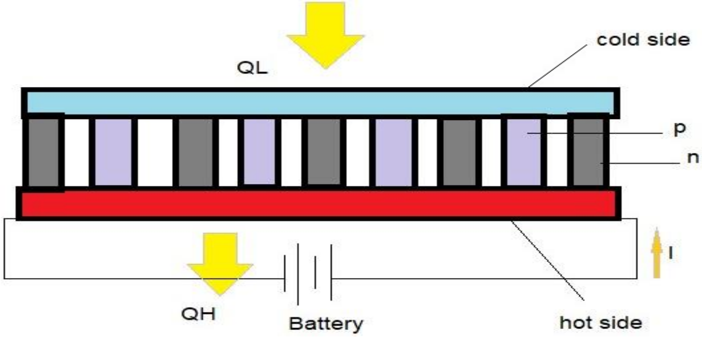


Figure 10. Transfer of Heat due to thermoelectric effect/Peltier

As seen in figure 10, QH stands for heat that the heat node release and QL stands for the heat that the cold node absorbs. When the temperatures of these two opposing plates differ, a Peltier devices generates voltage. On the other hand, when the voltage is supplies, each plate's stunning feature is its ability to flip the temperature characteristics when the polarities are switched in other words, if the battery packet or cell is heated using Terminal A, the same time terminal can be used to cool the surface of that battery packet or cell by switching the polarity of the voltage.

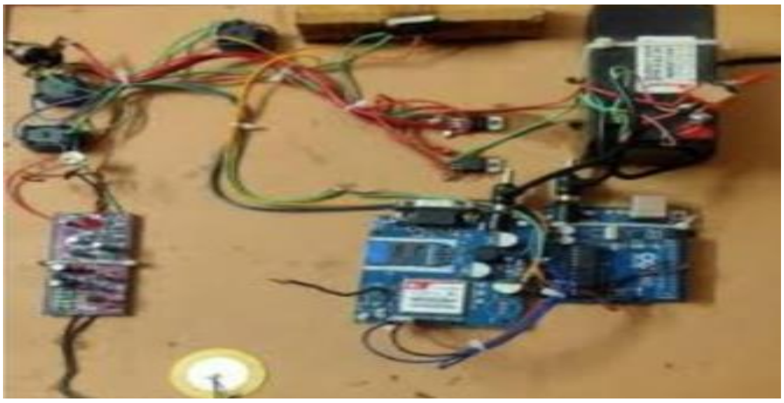
(h) Software Preparation

The Arduino Integrated improvement for Ecological(IDE) and AVR studio were used to enhance the Battery thermal and monitoring system checking Framework.

Arduino IDE: The Arduino IDE is an independent stage programme that utilise the c and c++ languages. It comes from the IDE and is used to sort programming languages.

6. Result

The executive performance of computationally efficient for battery thermal management of EV is user-friendly and straightforward to observe parameters like current, voltage and temperature of the battery through charging and discharging operation, and all parameters are monitoring the display using LCD to determine the user. The user will be alerted by a Buzzer if the battery temperature rises enough to trigger the cooling system, which kicks in if the battery begins to heat up slightly. If the battery temperature doesn't heat up drop. However, the battery shouldn't heat up and the temperature sensor sends values to the relay, LCD, and LCD-driven relay to shut off the motor respectively.



This system will serve as a safety measure for users of EVs and which is reduce several risks. This technology allows us to regulate various battery characteristics as well as battery temperature management. Users may also identify battery parameters assess whether a battery is normal or abnormal and know a battery is about to explode to cut down on fatalities.

7. Conclusion

The article explores the conceptualization, design, and implementation of an IoT-based battery thermal management and monitoring system for EVs. The goal is to make LCD screens capable of displaying the gradual decline in battery life. To increase the range of battery metrics like temperature, voltage, and current, it was necessary to implement the proposed Computationally Efficient for Battery Thermal and Monitoring system in EV. A battery monitoring and temperature management system with extremely high accuracy will be created in the future. It is anticipated that the simple and MPC systems discussed in this research will help make a sophisticated and effective this system a reality at the point. The system's viability as a Lithium-ion battery real time monitoring system was demonstrated via a working prototype based on the on-board monitoring device with connected sensors. In the future, we plan to use data from remote diagnostics and maintenance performed by repair personnel to precisely ascertain the states of the batteries involved in this project.

Declarations

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Competing Interests Statement

Authors have declared no competing interests.

Consent for Publication

The authors declare that they consented to the publication of this study.

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